Issues in sustainable transportation

Todd Litman*

Victoria Transport Policy Institute, 1250 Rudlin Street,
Victoria, BC, V8V 3R7, Canada
Fax: 250-360-1560 E-mail: www.vtpi.org
E-mail: info@vtpi.org
*Corresponding author

David Burwell

Project for Public Spaces, New York City, USA
E-mail: dburwell@pps.org

Abstract: There is growing interest in sustainability, sustainable development, and sustainable transportation. This paper identifies issues related to the definition, evaluation and implementation of sustainable transportation. Significant issues include the range of definitions of sustainability, the range of issues considered under sustainability, the range of perspectives, criticism of sustainability analysis, evaluating sustainability, transportation impacts on sustainability, goals vs. objectives, sustainable transport decision making, approaches to sustainable transport, automobile dependency, equity, land use, community liveability, and sustainable transportation solutions. Sustainable development originally focused on a few resource consumption issues, but it is increasingly defined more broadly to include economic and social welfare, equity, human health and ecological integrity. A narrow definition of sustainable transport tends to favour individual technological solutions, while a broader definition tends to favour more integrated solutions, including improved travel choices, economic incentives, institutional reforms, land use changes as well as technological innovation. Sustainability planning may require changing the way people think about and solve transportation problems.

Keywords: sustainable transportation; transport planning; transport economics; comprehensive planning; transport market reform; automobile dependency; equity; smart growth; paradigm shift.

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Biographical notes: Todd Litman is Founder and Executive Director of the Victoria Transport Policy Institute, an independent research organisation dedicated to developing innovative solutions to transportation problems. His research is used worldwide in transportation planning and policy analysis. He is active in several professional organisations, including the Institute of Transportation Engineers, the Transportation Research Board, and the Canadian Centre for Sustainable Transportation. He chairs the Transportation Research Board (a division of the US National Academy of Sciences) Sustainable Transportation indicators Subcommittee.

David Burwell Chairs the Transportation Research Board Task Force on Transportation and Sustainability, and serves on a panel on 'Combating Global

Warming Through Sustainable Surface Transportation Policy'. He is Director of Transportation Programs and Strategic Management for the Project for Public Spaces (www.pps.org), a nonprofit organisation dedicated to creating and sustaining public places that build communities. As a co-founder of the Rails-to-Trails Conservancy, and its President and CEO from 1986–2001, he created and managed a grassroots advocacy campaign to preserve America's system of abandoned rail corridors for conversion to trails and greenways. He was also a co-founder, fundraiser, President and CEO of the Surface Transportation Policy Project, a national coalition to change transportation policy and to restore balance in transportation service delivery.

1 Introduction

There is growing interest in sustainability, sustainable development, and sustainable transport. Many papers, reports and books have been published dealing with sustainability issues, and many communities are involved in sustainable planning projects. The nature and scope of these issues, and their implications for transportation planning and policy are only beginning to be explored.

Several factors contribute to interest in these issues. Concern about sustainability is rooted in the growing awareness that human activities have significant environmental impacts that can impose economic, social and ecological costs. Global air pollution, the durable effects of manufactured toxins, degraded natural resources such as fresh water and fisheries, and the cross-border nature of many environmental problems all highlight the need to view human impacts from a broad perspective.

Sustainability emphasises the integrated nature of human activities and therefore the need to coordinate planning among different sectors, jurisdictions and groups. Sustainability planning is to development what preventive medicine is to health: it anticipates and manages problems rather than waiting for crises to develop. Sustainable development strives for an optimal balance between economic, social and ecological objectives.

Sceptics might conclude that sustainable planning is simply a new name for comprehensive planning. This may be true, but many jurisdictions have done a poor job of such planning. The concept of sustainability provides a framework and tools for long-term, comprehensive planning, which recognises the complex relationships that transcend conventional geographic and temporal borders.

2 Defining sustainability

There is no universally accepted definition of sustainability, sustainable development or sustainable transport (Beatley, 1995). Definitions include:

> Sustainable development "meets the needs of the present without compromising the ability of future generations to meet their own needs." Brundtland Commission, 1987)

> "Sustainable development is the achievement of continued economic development without detriment to the environmental and natural resources." (Themes Sustainable Development, 2004)

> "The goal of sustainable transportation is to ensure that environment, social and economic considerations are factored into decisions affecting transportation activity." (MOST, 1999)

> "… sustainability is not about threat analysis; sustainability is about systems analysis. Specifically, it is about how environmental, economic, and social systems interact to their mutual advantage or disadvantage at various space-based scales of operation." (Transportation Research Board, 1997)

> Sustainability is "the capacity for continuance into the long term future". Anything that can go on being done on an indefinite basis is sustainable. Anything that cannot go on being done indefinitely is unsustainable (Center for Sustainability, 2004)

Concern about sustainability can be considered a reaction to the tendency in decision making to focus on easy-to-measure goals and impacts, while ignoring those that are more difficult to measure. Sustainable decision making can therefore be described as *planning that considers goals and impacts regardless of how difficult they are to measure*. Interest in sustainability originally reflected concerns about long-term risks of current resource consumption, reflecting the goals of 'intergenerational equity' (i.e., being fair to future generations) and ecological integrity. But if *future* equity and environmental quality are concerns, it makes little sense to ignore equity and environmental impacts that occur during this generation in distant places. Thus, sustainability ultimately reflects the goals of equity, ecological integrity and human welfare, regardless of time or location.

Ecological economics (a discipline concerned with valuing ecological resources) defines sustainability in terms of *natural capital*, the value of natural systems to provide goods and services, including clean air and water, and climatic stability (Jansson et al., 1994). Preserving these services is equivalent to a business maintaining the value of its productive assets. Ecological economists argue that consumption should not deplete natural capital at a faster rate than it can be replaced by viable and durable human capital. This suggests, for example, that non-renewable resources such as petroleum should not be depleted without sufficient development of substitutes, such as renewable energy sources.

Ecological economics attempts to account for non-market costs of economic activities, which tend to be ignored in traditional economics or even considered positive economic events by indicators such as gross domestic product (Daly and Cobb, 1989). This requires determining the economic value of non-market goods and services, such as the benefits that a wetland provides in terms of improving water quality and supporting fishing industries.

Sustainable economics maintains a distinction between *growth* (increased quantity) and *development* (increased quality) (Daly, 1996). It focuses on social welfare outcomes rather than simply measuring material wealth, and questions common economic indicators such as gross domestic product, which measure the quantity but not the quality of market activities. Unlike neoclassic economics, sustainable economics does not strive for ever-increasing consumption, but rather for *sufficiency*.

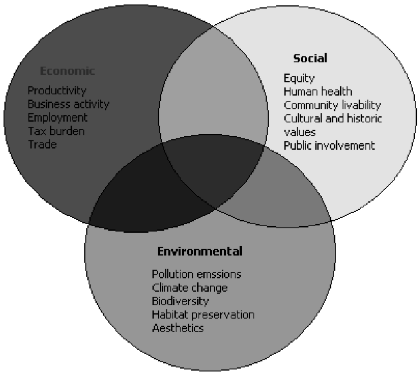
Sustainability tends to reflect a *conservation ethic*, which means that production and consumption patterns are structured to minimise resource consumption and waste. This requires changing current economic policies that encourage inefficient production and consumption. For example, many countries minimise energy prices in order to keep utilities and driving affordable, and to encourage manufacturing. That reflects a *consumption* ethic. A *conservation* ethic might increase energy prices (perhaps through a carbon tax) while implementing programmes to weatherise buildings, increase vehicle fuel efficiency, improve alternative modes, and increase industrial efficiency so that manufacturers and consumers can meet their needs with less resource consumption.

3 Range of issues

Sustainability is sometimes defined narrowly, for example, by focusing on resource depletion and air pollution problems, on the grounds that these represent the greatest long-term ecological risk and are prone to being neglected by conventional planning (Committee for a study on Transportation and a Sustainable Environment, 1997). But sustainability is increasingly defined more broadly to include the issues in Figure 1.

Although Figure 1 implies that each issue fits into a specific category, in practice they often overlap. For example, pollution is an environmental concern, which also affects human health (a social concern), and fishing and tourism industries (economic concerns). Sustainable planning reflects the realisation that impacts and objectives often interact, so solutions must reflect integrated analysis.

Figure 1 Sustainability issues



Narrowly defined sustainability tends to overlook many relationships between issues and opportunities for coordinated solutions. For example, some climate change emission reduction strategies may exacerbate other economic, social and environmental problems, while other strategies provide multiple benefits (Litman, 2004a). A comprehensive analysis can take into account these additional impacts, which a narrow analysis overlooks. Comprehensive analysis can identify *no regrets* solutions, which help achieve multiple objectives and are therefore justified regardless of the value assigned to costs such as global warming.

4 Transportation impacts on sustainability

Transportation facilities and activities have significant sustainability impacts, including those listed below.

Table 1 Transportation impacts on sustainability

Economic	*Social*	*Environmental*
Traffic congestion	Inequity of impacts	Air and water pollution
Mobility barriers	Mobility disadvantaged	Habitat loss
Accident damages	Human health impacts	Hydrologic impacts
Facility costs	Community interaction	DNRR
Consumer costs	Community liveability	
DNRR	Aesthetics	

DNRR: Depletion of non-renewable resources.

Until recently, most economists assumed that whatever its social and environmental costs, increased mobility provides net economic benefits. But new research indicates that beyond an optimal level, increased motor vehicle travel can have overall negative economic impacts because the marginal productivity of increased travel is declining, and vehicle use imposes external costs that can offset direct economic gains (Boarnet, 1997; Helling, 1997). This implies that sustainability planning does not always require tradeoffs between economic, social and environmental objectives, but rather a matter of finding strategies that help achieve all of these objectives over the long term by increasing transportation system efficiency.

Conventional planning tends to assume that transport progress is linear, consisting of newer, faster modes that displace older, slower modes as illustrated below. This *series model* assumes that the older modes are unimportant, and so, for example, there is no harm if increasing automobile traffic causes congestion delay to public transit or creates a barrier to pedestrian travel. From this perspective, it would be backward to give public transit or walking priority over automobile travel.

Walk → Bicycle → Train → Bus → Automobile → Improved automobiles

Sustainable reflects a *parallel model*, which assumes that each mode can be useful, and strives to create balanced transport systems that use each mode for what it does best. Transport progress therefore involves improving all useful modes, not just the newest mode, as illustrated below. For example, in many cities, the most beneficial strategies may involve improving walking and cycling, more support for public transit, and restricting automobile travel in congested urban areas. This does not assume that *improved transport* necessarily means faster travel or more mileage, improvements may increase comfort and safety, provide cost savings, or even reduce the total need for travel.

Walk → Improved walking conditions
Bicycle → Improved cycling conditions
Train/Bus → Improved public transit service
Automobile → Improved automobile travel conditions.

5 Sustainable transportation indicators

Sustainability is usually evaluated using a set of measurable indicators to track trends, compare areas and activities, evaluate particular policies and planning options, and set performance targets (Litman, 2003a; CST, 2001). Which indicators are selected can significantly influence analysis results. A particular policy or programme may rank high when evaluated using one set of indicators, but low when ranked by another set. There is a tension between convenience and comprehensiveness when selecting indicators. A smaller set of indicators using easily available data is more convenient to use but may overlook important impacts. A larger set can be more comprehensive, but may have unreasonable data collection costs.

It is important to avoid confusing goals and objectives when selecting indicators. *Goals* are what society ultimately wants. *Objectives* are things that help achieve goals, but are not ends in themselves. Decision makers sometimes focus on easy-to-measure impacts and objectives, while overlooking more-difficult-to-measure impacts and goals.

For example, the ultimate goal of most transport activity is *accessibility*, the ability to obtain desired goods, services and activities (VTPI, 2002). But access is difficult to measure, so transport planning tends to focus on traffic (vehicle movement) and mobility (the ability to move people and goods). This reduces the range of impacts and solutions considered in transport planning. For example, strategies for improving traffic and mobility can reduce access by degrading pedestrian conditions or creating dispersed land use patterns, while walking and cycling improvements, telework, and more accessible land use can improve access without increasing traffic or mobility.

5.1 Conventional transport indicators

Conventional transportation quality indicators mostly consider motor vehicles traffic conditions (Litman, 2003b). Below are examples:

- *roadway level-of-service*: a higher rating is considered better
- *average traffic speeds*: assumes higher is better
- *parking convenience and price*: increased convenience and lower price is considered better
- *crash rates per vehicle mile*: lower crash rates are considered better.

Because they favour motorised travel, these indicators tend to contradict sustainable transport objectives. For example, they justify roadway and parking capacity expansion that increases per capita vehicle travel and reduces walking, cycling and public transit use. This increases resource consumption, pollution emissions and land consumption, and exacerbating the transport problems facing non-drivers.

By evaluating impacts per *vehicle mile* rather than per capita, they do not consider increased vehicle mileage a risk factor or vehicle travel reductions as possible solution to transport problems. For example, from this perspective, an increase in per capita vehicle crashes is not a problem provided that vehicle mileage increases proportionately. Increased vehicle travel can even be considered a safety strategy if it occurs under relatively safe conditions, because more safe miles reduce per mile crash rates.

5.2 Simple sustainability indicators

To facilitate sustainable transportation analysis, some evaluations use a relatively simple set of indicators using relatively easily available data. Below are examples:

- transportation fossil fuel consumption and CO_2 emissions: less is better
- vehicle pollution emissions: less is better
- per capita motor vehicle mileage: less is better
- mode split: higher transit ridership is better
- traffic crash injuries and deaths: less is better
- transport land consumption: less is better
- roadway aesthetic conditions (people tend to be more inclined to care for environments that they consider beautiful and meaningful).

However, overly simple indicators may fail to provide effective planning guidance. They may overlook some important impacts (such as community liveability and equity), and they tend to favour solutions that address one or two specific objectives (such as alternative fuel vehicles), while undervaluing solutions that provide modest but multiple benefits (such as mobility management strategies and more accessible land use).

5.3 Comprehensive sustainable transportation indicators

Comprehensive sustainable transport indicators take into account a wide range of impacts. This should include indicators that reflect the full range of sustainability goals and objectives as indicated in Table 2.

Table 2 Sustainable transportation indicators

Objectives	*Indicator*	*Direction*	*Data*
Economic			
Accessibility – commuting	Average commute travel time	Less is better	3
Accessibility – land use mix	Number of job opportunities and commercial services within 30-minute travel distance of residents	More is better	1
Accessibility – smart growth	Implementation of policy and planning practices that lead to more accessible, clustered, mixed, multi-modal development	More is better	1
Transport diversity	Mode split: portion of travel made by walking, cycling, rideshare, public transit and telework	More is better	2
Affordability	Portion of household expenditures devoted to transport by 20% lowest-income households	Less is better	2
Facility costs	Per capita expenditures on roads, traffic services and parking facilities	Less is better	3
Freight efficiency	Speed and affordability of freight and commercial transport	More is better	1
Planning	Degree to which transport institutions reflect least-cost planning and investment practices	More is better	1

Table 2 Sustainable transportation indicators (continued)

Objectives	*Indicator*	*Direction*	*Data*
Social			
Safety	Per capita crash disabilities and fatalities	Less is better	3
Health and fitness	Percentage of population that regularly walks and cycles	More is better	1
Community liveability	Degree to which transport activities increase community liveability (local environmental quality)	More is better	1
Equity – fairness	Degree to which prices reflect full costs unless a subsidy is specifically justified	More is better	1
Equity – non-drivers.	Quality of accessibility and transport services for non-drivers	More is better	1
Equity – disabilities	Quality of transport facilities and services for people with disabilities (e.g., wheelchair users, people with visual impairments)	More is better	2
Non-motorised transport planning	Degree to which impacts on non-motorised transport are considered in transportation modelling and planning	More is better	1
Citizen involvement	Public involvement in transport planning process	More is better.	1
*Environmen*t			
Climate change emissions	Per capita fossil fuel consumption, and emissions of CO_2 and other climate change emissions	Less is better	3
Other air pollution.	Per capita emissions of ‘conventional’ air pollutants (CO, VOC, NO^x, particulates, etc.)	Less is better	3
Noise pollution	Portion of population exposed to high levels of traffic noise	Less is better	2
Water pollution	Per capita vehicle fluid losses	Less is better	1
Land use impacts	Per capita land devoted to transportation facilities	Less is better	1
Habitat protection	Preservation of wildlife habitat (wetlands, forests, etc.)	More is better	1
Resource efficiency	Non-renewable resource consumption in the production and use of vehicles and transport facilities	Less is better	2

Data availability: 1: limited, may require special data collection; 2: often available but not standardised; 3: usually available in standardised form.

Some of these indicators overlap. For example, there are several indicators of transport diversity (quality and quantity of travel options, mode split, quality of non-motorised transport, amount of non-motorised transport, etc.). It may be most appropriate to use just one such indicator, or if several similar indicators are used, give each a smaller weight.

Some indicators can be disaggregated by demographic (income, employment, gender, age, physical ability, minority status, etc.) and geographic factors (urban, suburban, rural, etc.), time (peak and off-peak, day and night), and by mode (walking, cycling, transit, etc.) and trip (commercial, commuting, tourism, shopping, etc.). Special consideration may be given to *basic access* trips, which society considers to have high value (travel to medical services, education, jobs, freight and commercial travel), and to the quality of transport for people with special needs (people who are unemployed, physically disabled, low-income single parents, socially disadvantaged groups, rural non-drivers, etc.).

Some indicators require data that may be difficult to obtain or evaluate. Some involve qualitative data using a subjective rating system rather than rather quantitative data using objective measurements. Data collection costs and ease of use should be considered when selecting indicators. However, indicators should not be selected based only on data availability, or some important objectives may be overlooked and undervalued.

Some important impacts are not reflected in these indicators but should not be ignored. For example, electric vehicles are often considered more sustainable, although their economic and environmental impacts depend on how electricity is produced. Although nuclear generation reduces some impacts (air pollution), it introduces others (radiation risk, thermal pollution, terrorist threats), and so does not necessarily increase sustainability.

Some indicators are ambiguous. For example, low per capita vehicle mileage could result from either undesirable conditions (poverty and highly congested roads) or desirable conditions (excellent transport options and efficient traffic management); hence, it is not a good indicator by itself. The best indicator of whether per capita vehicle mileage is optimal is the degree to which a transport system reflects market principles (cost-based pricing, consumer choice, neutral tax and investment policies, etc.) (VTPI, 2003). Because no jurisdictions have efficient transport markets (a few have implemented some market reforms, such as road pricing or least-cost transport planning practices, but none have implemented them all), virtually all areas have economically excessive levels of motor vehicle use (per capita vehicle travel would probably decline by a third or more if transport markets were truly optimal), and so vehicle mileage reductions can be considered to help achieve sustainability (Litman, 2004b). However, strategies that reflect market principles (more efficient pricing and more neutral planning practices) are more effective at achieving sustainability than more arbitrary strategies that restrict vehicle use.

6 Implications of sustainable transportation

Sustainability objectives have several implications for transport planning.

6.1 Transportation decision making

Sustainable transport planning requires a *paradigm shift*: a fundamental change in the way people think about and solve problems (Litman, 1999a). This involves more comprehensive analysis of impacts (including consideration of indirect and cumulative impacts), (Berger et al., 1998) consideration of a broader range of solutions than usually occurs, and more effective public involvement in transport planning.

Conventional planning reflects reductionist decision making, in which problems are assigned to a specialised organisation with narrowly defined responsibilities. One agency is typically given responsibility for solving traffic congestion problems, another reduces accidents, another protects the environment, while others determine the location of public facilities, such as schools. Often, one agency's solutions exacerbate another agency's problems.

Sustainable transportation planning requires more objective language. Traffic engineers traditionally describe any increase in road or parking facility capacity as an 'improvement', although from many perspectives (pedestrians, residents, aesthetics, and environmental quality) it may represent degradation. Sustainable transport planning avoids language biased in favour of automobile travel.

Sustainability suggests that public involvement is increasingly important because:

- it can result in decisions that more accurately reflect community values by giving people more opportunities to affect decisions
- it can contribute to more equitable transportation decisions by giving disadvantaged groups more involvement in decisions that affect them
- it can create more public support for policies that require behaviour changes or sacrifices in a community.

However, there is little agreement as to what this means in practice. Many transportation agencies already have public involvement procedures, and these impose resource and time costs. There is debate over how to best improve public involvement, and what amount of public involvement is adequate for sustainability. Public involvement based on community advisory committees is often dominated by local professional elite, while those based on public hearings require motivation and resources to become involved and so may be dominated by activists representing special interest.

6.2 Automobile dependency

Most sustainable transport planning supports reduced automobile dependency (defined as high levels of automobile use, automobile-oriented land use, and a lack of travel alternatives), since automobile dependency imposes various economic, social and environmental costs (OECD, 1996; Newman and Kenworthy, 1998; Litman, 1999b). However, some people argue that the benefits provided by automobiles far exceed these costs, that problems can be solved through technical improvements, that alternatives (such as public transit) are more harmful, and that automobile dependency is inevitable and so opposition is futile (Green, 1995).

This debate is often framed in terms of economic vs. environmental goals (sustainability requires sacrificing economic development objectives to protect the environment), but the issues are really more complex. Although a basic level of automobile use may provide economic benefits, there is evidence that beyond an optimal level, increased automobile use has negative economic impacts (Litman and Laube, 1999). Some researchers suggest that various market distortions contribute to excessive automobile dependency and vehicle designs that are more polluting and dangerous than optimal. These distortions include: (Litman, 2004b)

- dedicated funding for highway facilities that encourages roadway construction
- generous parking and road capacity standards
- zoning laws and development practices that favour automobile-oriented land use patterns
- unpriced roads and parking
- inexpensive automobile use since most vehicle costs are either fixed or external
- a lack of travel alternatives, including poor transit service and road conditions that are unfavourable for walking and cycling.

This suggests that reducing automobile dependency can achieve a more sustainable transport system, and that reducing market distortions can help achieve this objective.

6.3 Transportation equity

Equity has several potential implications for transport policy, but there are few guidelines to use in evaluating these various types of transportation equity. Below are some equity issues that could be considered in sustainable transportation planning.

- Horizontal equity implies that externalities of transportation should be reduced except where they are specifically justified. This includes reducing pollution emissions and accident risk from motor vehicle use, or compensating those who bear such external costs.
- Horizontal equity also implies that users should 'get what they pay for and pay for what they get', which could involve more road and parking fees, more accurate insurance pricing, and other pricing reforms.
- Vertical equity implies that access options should improve for people who are economically, socially and physically disadvantaged. This can include improved transit, ridesharing, cycling and walking conditions, and discounted prices for disadvantaged people.

6.4 Community livability

Community liveability includes local environmental quality, the quality of community interactions and community cohesion (whether community residents work together and support each other, sometimes referred to as 'civil society'), and the ability of a community to satisfy the basic needs of residents (such as food, shelter, education and medical services) (Gustavo and Manor, 1998; Putnam, 1993). Livability is considered a sustainability goal itself, and community liveability can support other sustainability objectives, such as reducing need to travel and increasing the use of public transit, ridesharing, cycling and walking.

Community liveability is sensitive to the quality of the public realm (public spaces where people can interact), of which the street system is a major component (Appleyard, 1981). This suggests that creating a more attractive, interactive, pedestrian-friendly streetscape, and other polities that encourage non-motorised transport, may be important for sustainable development (Burden, 1999).

6.5 Land use

Transportation patterns can be affected significantly by land use patterns (Moore and Throsnes, 1994; Kelly, 1994). In particular, low-density development, hierarchical street patterns, generous road and parking supply, and automobile-oriented site design tends to increase automobile dependency, leading to high levels of per capita motor vehicle mileage and a reduction in the quality of travel alternatives (transit, walking and cycling).

Many experts conclude that sustainable transportation requires higher-density land use patterns that accommodate alternative modes, and that cities with high-density neighbourhoods developed around passenger rail transit systems are the most sustainable model for urban areas (Newman and Kenworthy, 1998). Others argue that high-density development imposes costs; that most households will not willingly choose to live in high-density, transit-oriented cities; and that a low-density, automobile-oriented land use pattern are not necessarily more energy intensive than higher-density, transit-oriented cities (Gordon and Richardson, 1997).

7 Criticism of sustainability and sustainable transportation

Sustainability analysis has been criticised:

- Specific concerns such as climate change risks have been criticised as based on insufficient scientific information (Center for the Study of Carbon Dioxide and Global Change, 2004). Some agricultural scientists claim that climate change will provide net benefits to society (Green Earth Society, 2004). Other critics argue that the economic costs of sustainability objectives (such as Kyoto emission reduction goals) are excessive and inequitable (Center for Energy and Economic Development, 2004).
- Some critics argue that sustainability concerns ignore society's ability to accommodate change and overcome problems, and will excessively constrain economic activity and therefore social welfare (Simon, 1996). Some suggest that technology can correct environmental problems and resources can be extracted from beyond the earth if necessary.
- Sustainability is criticised for being such a broad and indefinite concept that it tends to be co-opted by special interest advocates, from nuclear power to ethanol subsidies, who highlight a particular 'sustainability' benefit. This is less a problem when more rigorous and comprehensive analysis is applied to identify the most optimal sustainability strategies.
- Sustainability objectives are criticised as unrealistic and overall harmful. For example, it may simply be impossible to meet climate change emission reduction targets due to a lack of cooperation between countries, and because conservation efforts may lead producers to reduce prices, resulting in increased consumption elsewhere. Similarly, restricting emissions in one location may simply shift manufacturing of resource-intensive products to other, less restrictive regions.

- Objectives to reduce automobile use are criticised in particular as being unrealistic and inequitable if they deprive lower-income consumers of their preferred mode of transport. Strategies such as pricing reforms, HOV facilities and traffic calming are sometimes called 'draconian' and an unacceptable government imposition on citizens' behaviour.

8 Sustainable transportation solutions

Many strategies have been proposed to create more sustainable transportation, including various planning, management and technical changes. Sometimes, the choices are presented as one option *or* another, but most research indicates that a combination of strategies is needed to achieve sustainability goals. 'No regrets' solutions help achieve a combination of economic, environmental and social objectives, and so can be implemented regardless of uncertainty over the value placed on environmental and social impacts, such as global warming and inequity. However, there are often significant debates over which strategies are most appropriate, which deserve the most investment, and when each should be implemented.

Sustainability polices often involve conflicts between different interests and regions, even when their overall impacts are positive. For example, energy conservation will reduce income and profits for energy producing companies and regions. Although these are economic transfers, not true costs, they involve transition costs and conflicts. Sustainability planning may therefore require strategies to compensate those who lose, and programmes to facilitate the transition to a more resource efficient economy. This has many implications in various transportation industries, such as the petroleum and automobile industry, which are likely to decline if some sustainability policies are implemented.

Table 3 summarises sustainability goals and objectives, the transportation objectives that experts recommend, and solutions that have been proposed to achieve these objectives.

Table 3 Summary

Sustainability goal	*Sustainability objective*	*Transportation objective*	*Transportation solution*
Ecological integrity	Reduce climate change	Reduce climate change emissions	CAFE standards, emission taxes, TDM, alternative fuels
	Preserve wildlife habitat	Reduce impervious surface	Reduce parking and road capacity standards, TDM, parking management, design roads to minimise habitat impacts, encourage higher-density, infill development
	Reduce pollution	Reduce harmful vehicle air and water emissions	Emission standards, TDM, I/M programmes

Table 3 Summary (continued)

Sustainability goal	*Sustainability objective*	*Transportation objective*	*Transportation solution*
Human health	Reduce injuries	Reduce traffic accidents	Crash prevention, crash protection, TDM
	Reduce pollution exposure	Criteria emission controls	Emission standards, I/M programmes, alternative fuels, TDM
	Increase exercise	Increase active transport	Improve walking and cycling conditions, traffic calming, encourage non-motorised transport, TDM
Economic welfare	Consumer's mobility	Insure adequate transport services, provide mobility choices, reduce traffic congestion and barriers	Adequate road capacity, transit services, TDM, walking and cycling improvement, lovable communities, delivery services
	Business productivity	Freight mobility and affordability, facility siting options	Adequate road/rail/air freight capacity, efficient land use, freight priority, TDM
Economic welfare	Public investment productivity/tax reductions	Transportation facility and service efficiency	Planning and management for efficiency, efficient pricing, TDM
Equity	Horizontal equity	User pay principle	Cost-based pricing, internalise externalities, reduce externalities
	Vertical equity	Progressive pricing	Low prices/taxes for ;basic' driving, transit
		Mobility for non-drivers	Provide adequate walking, cycling, rideshare, transit services; multi-modal community/land use
Social welfare	Community cohesion and liveability	Improve mobility within neighbourhoods	Neotraditional street planning, traffic calming, pedestrian/cycle planning, mixed land use
		Enhance the public realm through street improvements	Traffic calming, pedestrian planning, liveable community design features

TDM: Transportation demand management, various strategies to change travel behaviour (VTPI, 2004).

CAFE: Corporate average fleet efficiency, a standard based on the overall average fuel efficiency of all vehicles sold by each manufacturer.

9 Visions of sustainable transportation

There are two basic perspectives of sustainability problem solving. A 'reductionist' approach considers sustainability a narrow set of *individual* problems that can be addressed using existing transportation planning in which experts rank problems and solutions. This assumes that growing travel volumes can continue, provided that the most critical sustainability objectives are addressed in vehicle design.

A 'comprehensive' perspective assumes that sustainability is a broad set of *integrated* problems that cannot be solved using existing transportation decision–making practices, which allows solutions to one problem that exacerbate others. This perspective suggests that sustainability requires a reduction in total travel volumes.

These perspectives lead to the visions of sustainable transportation described later. Most sustainable transport plans actually employ a combination of these approaches, including improved travel choices, pricing and road design incentives to encourage more efficient travel choices, land use patterns that reduce the need to travel and support alternative modes, and technical improvements to the motor vehicles that are used.

Technical (Dudson, 1998)

This vision relies on technological innovation to solve specific sustainability problems, create wealth and increase mobility. New production techniques (e.g., nuclear power, recycled materials), alternative fuel and super-efficient vehicles, Intelligent Transportation Systems (ITS), and increased highway capacity are typical components of this vision.

Demand management (Transportation Association of Canada, 1999)

This vision involves changing travel behaviour, including shifts in travel time, route, mode and destination. It involves a number of specific components (some described later) that increase traveller choice and encourage more economically efficient travel patterns.

Economic reform (Litman, 2004b)

This vision relies on creating a more optimal transportation market by reforming transport prices and investment practices. It includes full-cost pricing (i.e., charging motorists directly for the marginal costs they impose), congestion pricing, tax shifting and least-cost planning.

Alternative modes

These involve improvements to public transit (which can include heavy rail, trolley, express bus, conventional fixed-route bus, minibus, demand-response paratransit, personal rapid transit, jitney, vanpool and taxi) and ridesharing, non-motorised transport, and telecommuting, including road design features that give priority to these modes.

Land use/community design changes (Newman and Kenworthy, 1998)

These involve changing land use patterns to reduce travel distances and increase mode choice, for example, by locating more services and jobs near residential neighbourhoods, and by creating neighbourhoods that are more suitable for public transit, walking and cycling.

10 Conclusions

Sustainable transportation planning raises a number of issues regarding the definition of sustainability and sustainable transportation, how goals and objectives are defined and evaluated, and the type of decision-making process that should be used.

Sustainability requires more comprehensive and integrated planning, which accounts for a broad set of economic, social and environmental impacts, including those that are difficult to measure. Sustainability planning requires adequate stakeholder involvement to allow diverse perspectives and preferences to be incorporated.

Sustainability tends to support transportation planning and market reforms that result in more diverse and economically efficient transportation systems, and more compact land use patterns that reduce automobile dependency. These reforms help increase economic efficiency, reduce resource consumption and harmful environmental impacts, and improve mobility for non-drivers.

Although it is relatively easy to define the general type of policy changes that support sustainable transportation, it may be difficult to define exactly what degree of change is needed.

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